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The value of autopsy in preterm infants at a Swedish tertiary neonatal intensive care unit 2002–2018

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Reliable data on causes of death (COD) in preterm infants are needed to assess perinatal care and current clinical guidelines. In this retrospective observational analysis of all deceased preterm infants born < 37 weeks' gestational age (n = 278) at a Swedish tertiary neonatal intensive care unit, we compared preliminary COD from Medical Death Certificates with autopsy defined COD (2002–2018), and assessed changes in COD between two periods (period 1:2002–2009 vs. period 2:2011–2018; 2010 excluded due to centralized care and seasonal variation in COD). Autopsy was performed in 73% of all cases and was more than twice as high compared to national infant autopsy rates (33%). Autopsy revised or confirmed a suspected preliminary COD in 34.9% of the cases (23.6% and 11.3%, respectively). Necrotizing enterocolitis (NEC) as COD increased between Period 1 and 2 (5% vs. 26%). The autopsy rate did not change between the two study periods (75% vs. 71%). We conclude that autopsy determined the final COD in a third of cases, while the incidence of NEC as COD increased markedly during the study period. Since there is a high risk to determine COD incorrectly based on clinical findings in preterm infants, autopsy remains a valuable method to obtain reliable COD.

Abbreviations

BPD	Bronchopulmonary dysplasia
COD	Cause of death
IVH	Intraventricular hemorrhage
MDC	Medical death certificate
NEC	Necrotizing enterocolitis
RDS	Respiratory distress syndrome
SNQ	Swedish neonatal quality registry
UUCH	Uppsala University Children's Hospital

The autopsy has been fundamental to understand anatomy and pathophysiology in medicine and neonatology. Despite proactive obstetric and neonatal care, prematurity remains the most common worldwide cause of death (COD) among children under the age of 5 years^{1,2}. As autopsy is “the gold standard” for accurately determining COD, autopsy contributes to the continued development of neonatal care and possibly improved survival in preterm infants^{3,4}.

When reporting causes of death, it is customary to use the International Classification of Diseases (ICD) by the WHO⁵. To assign prematurity as the COD is not recommended by the WHO, unless no other COD can be confirmed. Despite these recommendations, there has been a continued use of prematurity as COD instead of defining the specific COD^{6–8}. In mortality reports, ICD-codes are grouped into categories to provide coherent descriptions, although, classification systems often differ between reports and/or countries. Based on Wigglesworth's classification of perinatal mortality⁹, the International Collaborative Effort (ICE) offered a classification method for infant mortality in 1989 to enable international comparisons¹⁰. Still, reports continue to use different classifications^{11–14}, and some, including the ICE, use the classification of prematurity related deaths despite the recommendations from the WHO⁸. New classification systems have been proposed, yet no consensus has

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	Both periods	Period 1 2002–2009	Period 2 2011–2018	<i>p</i> value
Population size	265	105	160	–
Gestational age, weeks—median (range)	25 (21–36)	26 (21–36)	25 (21–36)	0.255
Birth weight, g—median (range)	742 (312–3970)	800 (312–3655)	710 (322–3970)	0.256
Gestational age of those deceased—number (% of total in period)				
32–36 weeks	37 (14.0)	16 (15.2)	21 (13.1)	0.627
28–31 weeks	51 (19.2)	19 (18.1)	32 (20.0)	0.700
<28 weeks	177 (66.8)	70 (66.7)	107 (66.9)	0.972
Distribution of sex—number (% of total in period)				
Girls	109 (41.1)	50 (47.6)	59 (36.9)	0.265
Boys	156 (58.9)	55 (52.4)	101 (63.1)	0.373
Postnatal age at death in days—median (range)	7(0–308)	5 (0–239)	8 (0–308)	0.361
Timing of death—number (% of total in period)				
0–24 h	38 (14.3)	15 (14.3)	23 (14.4)	0.234
1–6 days	90 (34.0)	41 (39.0)	49 (30.6)	0.230
7–28 days	80 (30.2)	29 (27.6)	51 (31.9)	0.635
>28 days, up to one year	57 (21.5)	20 (19.0)	37 (23.1)	0.429

Table 1. Characteristics of deceased infants.

been reached^{15,16}. In Sweden, death is certified in two stages: the Notification of Death and the Medical Death Certificate (MDC)⁶. Writing a MDC to define COD utilizes the WHO guidelines. A chronology of events leading to death is listed in the MDC, including the duration of each condition. The direct COD is defined as the final condition causing death^{5,6}.

Unfortunately, there is a global trend for decreasing autopsy rates in infants¹⁷, which has also been seen in Sweden. A report from 2014 showed that infant autopsy rates had decreased from 71 to 35% for boys and from 64 to 31% for girls since 1987⁷. The former chief editor of JAMA George Lundberg warned in 1988 that autopsy reduction will negatively affect provided care, since lack of quality control of care will result in reduced knowledge of beneficial or negative effects of treatments¹⁸. Accurately defined COD reports are also needed for reliable and meaningful statistics. Records of preterm deaths are frequently incorrect, with flaws in the definition of live births, underreporting of births and deaths, and inaccurately stated CODs¹⁹. Some have advocated for postmortem MRI as a supplement to autopsies^{20,21}. Although MRI brings some diagnostic value, it has been shown to miss more than half of the findings an autopsy would have provided, and neglects histological and microbiological features^{20,21}.

The aim of this study was to determine the incidence of autopsy in preterm infants treated at our NICU between 2002 and 2018, and define how many of the preliminary CODs were revised by these autopsies. We also wanted to determine if there have been changes in the CODs over time. A better understanding of the significance of accurately determining the COD by autopsy in preterm infants may lead to the development of standardized protocols for defining COD.

Results

The mortality for all premature infants born in Uppsala was 3.8% ($n = 105/2763$) during Period 1 and 5.0% ($n = 160/3200$) during Period 2 ($p = 0.059$). A total of 278 infants died during 2002–2018. No differences in birth weight, gestational age, degree of immaturity or age at death was found between the two periods (Table 1). There was a higher percentage of boys who died compared to girls in Period 2 (63.1% vs. 36.9%; $p = 0.006$; Table 1).

Autopsy data are summarized in Table 2. The autopsy rate over the whole study period was 73.0% ($n = 203/278$), and did not change between the study periods (75% vs. 71%). Boys were autopsied in 70.2% of cases and girls in 76.9%. The main reason for an autopsy not being performed was parental refusal ($n = 61/75$; 81.3%). In 14.7% cases, there was no declared reason for autopsy not being performed. The frequency of autopsies was lower in those who died after 7 days of life ($n = 96/141$; 64.9%) as compared to those who died earlier ($n = 107/137$; 78.1%). Postmortem examinations changed the preliminary COD or confirmed the suspected COD in 35.0% ($n = 71/203$) of all autopsied cases (23.7% of the preliminary CODs were revised completely, and 11.3% of the suspected CODs were confirmed). In 5% ($n = 10/203$) of the autopsied cases it was not possible to define if autopsy altered the COD, due to lack of data on the preliminary COD. In Supplement 1, the preliminary COD and autopsy confirmed COD is listed for each individual where autopsy completely revised the COD. The CODs where autopsy enabled confirmation of a suspected COD are also listed in Supplement 1.

Cause of death: comparison between Period 1 and Period 2. NEC as the COD increased from 5.0% ($n = 5/101$) to 25.2% ($n = 40/159$) ($p < 0.001$) from Period 1 to Period 2, whereas IVH as the COD decreased ($p = 0.042$) (Table 3). The annual incidence of NEC as a COD is shown in Fig. 1. Period 2 had fewer cases of RDS ($p = 0.039$) as COD than Period 1. The isolated spontaneous intestinal perforations ($n = 4$) were either consequences of anomalies or perforation without NEC. The type of infections as the COD during Period 1 and Period 2 was viral ($n = 2$), fungal ($n = 2$), bacterial pneumonia ($n = 3$) and systemic bacterial ($n = 34$).

	Number	Percent
Number of performed autopsies	203/278	73.0
Revised CODs after autopsy	48/203	23.6
Confirmed suspected CODs after autopsy	23/203	11.3
Not changed CODs after autopsy	112/203	55.2
Clinical CODs more precise than autopsy CODs*	10/203	4.9
Not available	10/203	4.9
Revised and confirmed suspected CODs after autopsy	71/203	34.9
Congenital anomaly	6/71	8.5
Asphyxia	1/71	1.4
Respiratory	13/71	18.3
IVH	4/71	5.6
Infection/sepsis	21/71	29.6
NEC	14/71	19.7
Other	12/71	16.9
Reasons for not performing autopsy	75/278	27.0
Parental refusal	61/75	81.3
Lack of medical indication	2/75	2.7
Other	1/75	1.3
Unknown	11/75	14.7

Table 2. Number of performed autopsies, diagnosis after autopsy of revised and confirmed suspected causes of death (CODs), and reasons for not performing autopsy (2002–2018). *If the autopsy defined the COD as “prematurity”, the clinical diagnosis was used as a definitive COD. In 3 of these 10 cases, the clinical COD was also prematurity.

Cause versus timing of death. As shown in Fig. 2a, fewer patients died due to perinatal asphyxia between day 1–6 ($p=0.050$) in Period 2 than in Period 1. Cases with NEC as the COD increased for infants who died on days 7–28 and after 28 days ($p=0.001$ and $p=0.025$, respectively), while infection as the COD decreased ($p=0.006$) between Period 1 and 2 for those infants who died on days 7–28. Median days of life for patients with NEC as cause of death was 4 (IQR=8.5) in Period 1 and 11 (IQR=11.5) in Period 2 ($p=0.023$).

Cause of death versus degree of immaturity. As presented in Fig. 2b, the incidence of NEC as COD in Period 2 was higher than in Period 1 for very preterm ($p=0.028$) and extremely preterm infants ($p<0.001$). There were no other significant differences in COD in the gestational age groups between Periods 1 and 2 (Fig. 2b).

Discussion

In this study involving 278 preterms, we found an autopsy rate of 73% and a comparable distribution between sexes. The autopsy rate in this cohort was more than twice as high compared to national rates of infant autopsies in Sweden⁷. This might be explained by our local tradition of offering postmortem investigations at a regular basis to all parents in order to increase autopsy rates in preterm infants at UUCH, and thereby improving our knowledge of the COD. Infants who died at a higher postnatal age were autopsied less frequently than those who died at a lower postnatal age. Although unclear from this study, this difference in autopsy rates depending on postnatal age may be a consequence of there being more time to find a definitive diagnosis during a longer stay at the NICU, which is partly substantiated by de Séveaux et al. who found only minor additional findings with higher postnatal age at death²¹. Parents refusing to consent to autopsy was the main reason for autopsies not taking place, which is in agreement with previous findings^{21,22}. Reduced parental consent may depend on the information provided by the health care regarding the procedure and potential benefit of an autopsy^{22,23}. In many cases, the responsibility for obtaining consent for autopsy lies with the medical staff who may not fully understand the importance of the autopsy when discussing the procedure with the parents^{22,23}. For the parents, the correct COD for their lost infant may be of importance for future pregnancy decisions, since genetic anomalies or syndromes can be difficult to diagnose solely on clinical examination of very preterm infants²¹.

Our main finding is that post-mortem examinations contributed considerably to determining the COD as evidenced by changing or confirming the suspected preliminary COD in a third of cases. This is consistent with results from previous studies, where a percentage of 25–36% CODs were found to be altered by autopsy in centers with generally low autopsy rates^{21,22,24}. A higher autopsy rate might be expected to decrease the number of times the preliminary COD is revised, given that in studies with lower autopsy rates, the autopsy is performed when the COD is unclear to the clinician^{17,21,25}. However, as shown in this study, even with relatively high autopsy rates the risk of changing the preliminary COD remains high. Thus, our data are consistent with the notion that improving autopsy rates will yield a higher quality of COD and therefore be more useful in understanding COD trends in the NICU.

The decrease of IVH as a COD between the two studied periods, is consistent with national findings in Sweden²⁶ and may be attributed to more refined ventilatory strategies²⁷ and more consistent treatment with

	Both periods	Period 1 2002–2009	Period 2 2011–2018	p value
Total deaths (n)	265	105	160	–
Total deaths with determined cause of death (n)	260	101	159	–
Cause of death—number of cases (% of total)	n	n (%)	n (%)	
Congenital anomalies	18	10 (9.9)	8 (5.0)	0.132
Neural anomaly	3	2 (2.0)	1 (0.6)	0.562
Cardiac anomaly	3	2 (2.0)	1 (0.6)	0.562
Other anomaly	9	3 (3.0)	6 (3.8)	1.000
Chromosomal abnormalities	3	3 (3.0)	0 (0.0)	0.058
Asphyxia	17	10 (9.6)	7 (4.4)	0.080
Intrauterine	8	4 (4.0)	4 (2.5)	0.715
Perinatal	8	6 (5.9)	2 (1.3)	0.059
Postnatal	1	0 (0.0)	1 (0.6)	1.000
Respiratory	75	31 (30.7)	44 (27.3)	0.674
RDS	10	7 (6.9)	3 (1.9)	0.039
BPD	12	5 (5.0)	7 (4.4)	0.837
Pulmonary hypoplasia	20	8 (7.9)	12 (7.5)	0.912
PPHN	10	5 (5.0)	5 (3.1)	0.461
Pneumothorax	5	1 (1.0)	4 (2.5)	0.651
Haemothorax	4	3 (3.0)	1 (0.6)	0.302
Miscellaneous	14	2 (2.0)	12 (7.5)	0.087
IVH	22	13 (12.9)	9 (5.7)	0.042
Infection/sepsis	41	19 (18.8)	22 (13.8)	0.283
Early	11	3 (3.0)	8 (5.0)	0.537
Late	30	16 (15.8)	14 (8.8)	0.083
NEC	45	5 (5.0)	40 (25.2)	<0.001
NEC with Sepsis	16	2 (2.0)	14 (8.8)	0.053
NEC without sepsis	29	3 (3.0)	26 (16.4)	0.001
Other	42	13 (12.9)	29 (18.2)	0.252
Shock/anemia/bleeding	8	1 (1.0)	7 (4.4)	0.156
Volvulus/malrotation	4	1 (1.0)	3 (1.9)	1.000
Isolated spontaneous intestinal perforation	4	0 (0.0)	4 (2.5)	0.160
Metabolic/electrolyte/endocrine disorders	4	2 (2.0)	2 (1.3)	0.643
Tumor	3	0 (0.0)	3 (1.9)	0.285
Twin-twin transfusion syndrome	2	2 (1.0)	1 (0.6)	0.562
CNS-related	3	1 (1.0)	2 (1.3)	1.000
Other	8	4 (4.0)	4 (2.5)	0.715
Prematurity	3	2 (2.0)	1 (0.6)	0.562
Unknown	2	0 (0.0)	2 (1.3)	0.523

Table 3. Cause of death in relation to year of birth.

antenatal corticosteroids²⁸. Being a referral hospital for our region, the reduced rate of RDS as a COD could be due to the changed policy during Period 2 of referring all mothers at risk of delivering prematurely before 28 weeks GA to our hospital, an observation that needs further evaluation. We found that the incidence of congenital anomalies as a COD in our cohort was lower than in other comparable studies in high income countries²⁹. One possible explanation could be consistent maternity care, improved prenatal screening for congenital anomalies and Swedish abortion practices. Another reason could be the targeting of a more precise COD in our study rather than applying a general diagnosis like congenital anomalies as the primary COD.

The occurrence of NEC as the COD was significantly higher during Period 2 as compared to Period 1. The increase of NEC was especially evident in extremely preterm infants and deaths during day 7–28 and after 28 days of life. This is likely due to NEC being a disease occurring after 1–2 of weeks of life³⁰ and that the risk of NEC increases with decreasing gestational age³¹. Another potential factor in the overall increase of NEC as a COD could be that improvements in clinical care over time enable the infants to survive long enough to develop NEC, as has been suggested previously³². The median age at death for patients with NEC as COD increased significantly between Period 1 and Period 2. An increased incidence of NEC in Sweden has also been reported for these two time periods (2004–2007 vs. 2014–2016; 6% vs. 10%) with a simultaneously increased survival in the lowest gestational ages (70% vs. 77%)³³. A lower reported incidence of surgically treated NEC from our unit to the Swedish Neonatal Quality Register in infants born between 22 and 27 weeks GA (22–24 GA, 5% vs.

Annual Incidence of NEC as Cause of Death

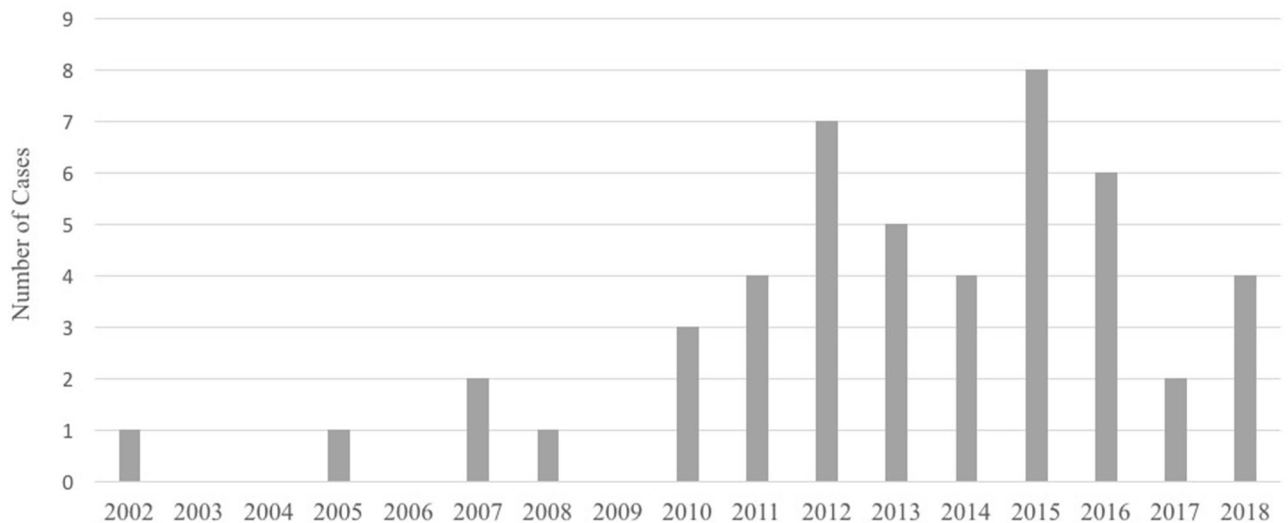


Figure 1. Annual incidence of NEC as cause of death from 2002 to 2018.

7.5%; 25–27 GA, 1.5% vs. 3%)²⁶, with similar to lower mortality rates, suggests that other factors than local case clustering of NEC from viral or bacterial outbreaks (so called epidemic NEC) contribute to NEC incidence in our study^{34,35}. The increase in NEC as a COD cannot be only ascribed to more autopsies allowing more detailed diagnosis, since the autopsy rate was similar during both periods. Nor could any difference in breast-feeding strategies (same during both periods) or probiotic strategies (not introduced) explain this redistribution of CODs with higher NEC during the second period.

The retrospective observational study design seems relevant for this type of study, and seems to define the prevalence of different CODs and the value of autopsy in determining the definitive COD. However, given the observational design it is difficult to draw too strong conclusions regarding the causes for the observed changes in COD over time, and particularly for NEC, why further research is needed to explain these differences in COD. Structured national and international surveying of neonatal care is increasing worldwide³⁶, and might have impact on understanding COD and changes in COD over time. Some other studies on infant mortality have systematically assigned prematurity as the major COD¹³, ignoring the recommendations of the WHO⁸. We found 10 cases in this cohort where prematurity was registered as the COD, however 7 of them could later be sorted into other categories using data from medical records and/or autopsies. Only in 3 out of 278 cases did prematurity remain as the final COD. The low rate of prematurity as COD demonstrates the feasibility of following the WHO recommendation regarding not assigning prematurity as the primary COD. Some of the complications of prematurity are difficult to diagnose in preterm infants, since symptoms may not be specific or may appear after a delay. In our study, nearly 75% of all diagnoses were autopsy-verified, substantiating the COD. All autopsies were performed by the same pathologist, which results in a high level of qualitative continuity in performing autopsies²². In addition, the neonatologist involved in the patient's care usually attended the postmortem examination, thereby providing the pathologist with more detailed pre-mortem clinical findings, which facilitated the examination and supported the definitive COD.

This study highlights the importance of post-mortem examinations, which continue to yield valuable information and contribute to determine the definitive COD in preterm infants. Besides observing an increase in NEC and a decrease in IVH between the two periods, we found that the results from the autopsy revised or confirmed the suspected preliminary COD in a third of cases during the entire study period. Interestingly, 73% of all deceased preterm infants during this period were autopsied and not only the ones with uncertain diagnoses. Our findings suggest that it would be beneficial to reverse the negative trend in autopsy rates in preterm infants, in order to obtain reliable COD data.

Methods

Study setting and ethical consideration. This study is a retrospective observational study of all preterm deaths from 2002 to 2018 and a 2-period sub-analysis (2002–2009 vs. 2011–2018) in a tertiary NICU at Uppsala University Children's Hospital (UUCH). In order to exclude overlap of early and late deaths, and seasonal variations in COD, 2010 was excluded from the 2-period analysis. The study has been approved by the Regional Ethical Review Board of Uppsala, D:nr 2019-05033, and by the Uppsala Biobank, D:nr BbA-827-2019-094. With these endorsements infants were legally approved to be included in this study. Parental informed consent to perform an autopsy was obtained. All methods in this study were performed in accordance with relevant operating guidelines and regulations. Data were de-identified before analysis, according to operative ethical regulations.

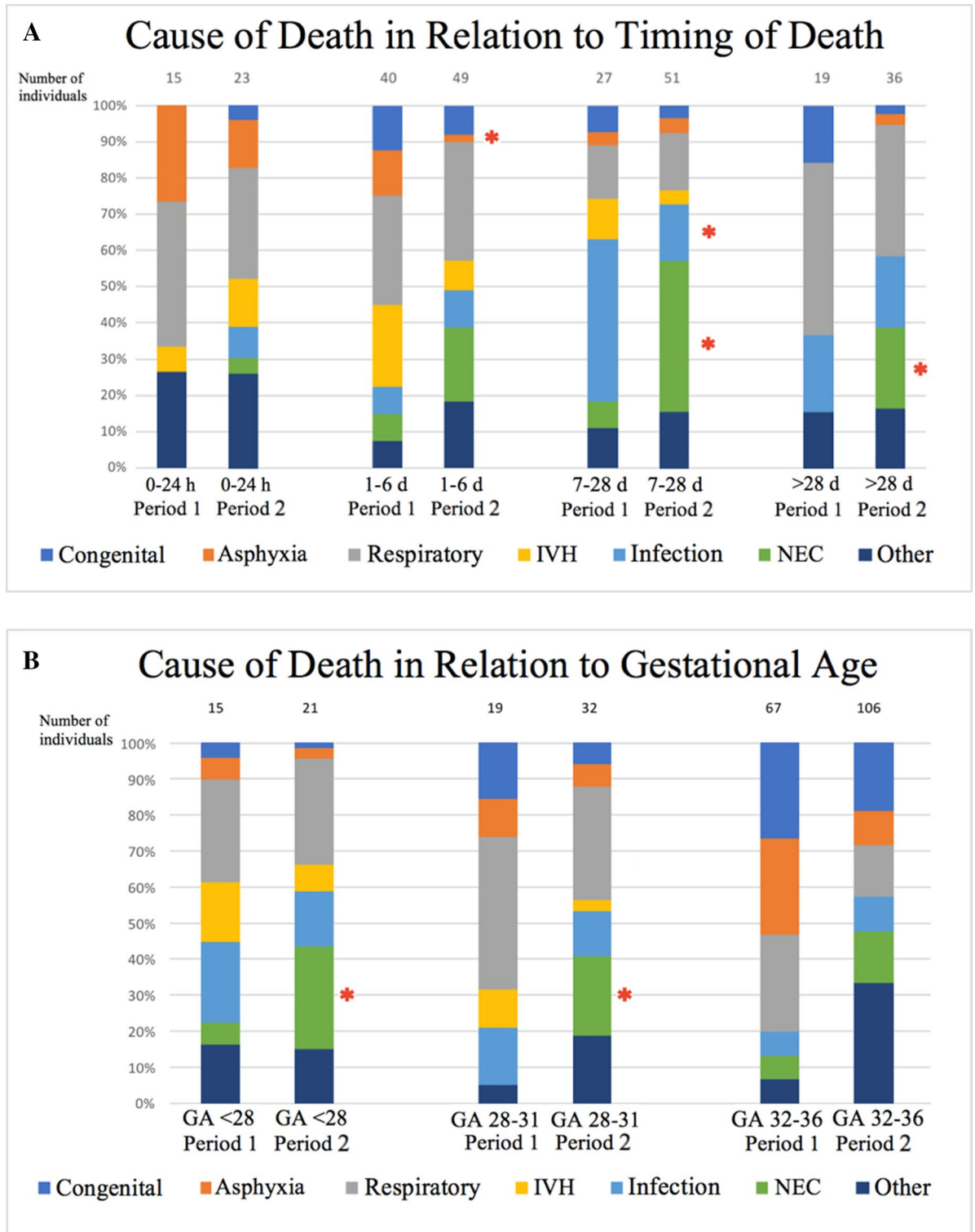


Figure 2. (a) Distribution in percent of causes of death at various time intervals (0–24 h; 1–6 days; 7–28 days; >28 days) during Period 1 and Period 2. * $p < 0.05$; significant change between Period 1 and Period 2 within each time interval. Congenital, congenital anomalies; Respiratory, respiratory causes; IVH, intraventricular hemorrhage; Infection, infection with septicemia; NEC, necrotizing enterocolitis. See Table 4 for further categorization of causes of death. (b) Distribution in percent of causes of death at various degrees of immaturity (gestational age <28 weeks, 28–31 weeks and 32–36 weeks) during Period 1 and Period 2. * $p < 0.05$; significant change between Period 1 and Period 2 within each degree of immaturity. GA; gestational age; Congenital, congenital anomalies; Respiratory, respiratory causes; IVH, intraventricular hemorrhage; Infection, infection with septicemia; NEC, necrotizing enterocolitis. See Table 4 for further categorization of causes of death.

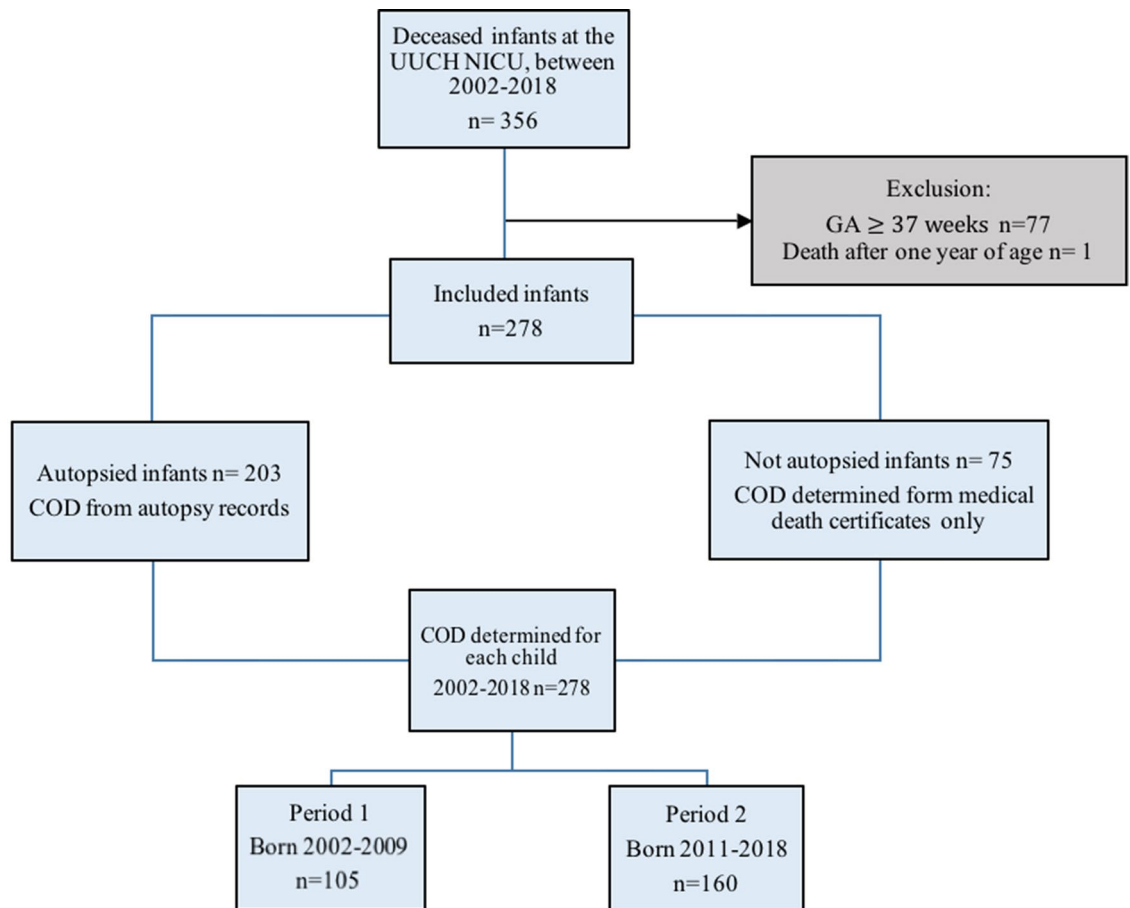


Figure 3. Inclusion of participants, data extraction and period division.

Inclusion of participants. Figure 3 shows a flowchart of the selection of participants. All live born infants admitted to our NICU who subsequently died during the period of 2002 to 2018 were extracted from the Swedish Neonatal Quality Registry (SNQ) (n = 356). To study solely infant mortality, patients who died after 1 year of age were excluded (n = 1). Term infants (≥ 37 weeks gestation) were excluded (n = 77). Thus, there were a total of 278 infants that met inclusion criteria and had none of the exclusion criteria.

For the comparison between preliminary COD and definitive COD according to autopsy, there were 203 infants with an autopsy (Fig. 3). Medical Death Certificate (MDCs) were examined to determine preliminary cause of death. If multiple MDCs were issued, the MDC issued prior to autopsy was used to avoid the preliminary COD being influenced by autopsy findings. If the MDC was issued after autopsy findings, the discharge note was examined to determine the presumed COD prior to autopsy. MDC and the discharge note were written by the attending physician well acquainted with the patient, and confirmed by the head physician in charge of the ward. An autopsy included a macroscopic review of tissues with a neonatologist present, immune-histological analysis linked to symptomology, bacterial cultures and PCR-analysis if suspicion for viral infection from clinical symptoms or from macroscopic findings was present. The present neonatologist provided clinical data, contributing to the definitive cause of death as determined by autopsy. All infant autopsies were performed by the same pathologist and none was restricted in scope. Parental informed consent was required for autopsy. All parents are offered autopsy by the attending physician on a regular basis, to define the definitive COD and/or other diseases relevant for the course of care and for future pregnancies. For the individuals who were not autopsied, the reason for an autopsy not being performed was defined.

Data extraction and study variables. Perinatal and postnatal data were collected from the SNQ. Perinatal data included time of birth, GA, sex, and birth weight. GA was documented as complete weeks and days, determined by ultrasound. Postnatal data included whether autopsy was performed or not, days of life, and if recorded, why an autopsy was not performed. If the autopsy was not performed due to parental reluctance no retrospective inquiry was performed, since this was considered ethically inappropriate. Missing data in SNQ were complemented by retrieving Medical Death Certificates (MDC) and charts from Cosmic (electronic journal database after 2008) or from Regional archives (before 2008). Autopsy records were collected from the pathology chart system Sympathy. Premature birth rates for the Uppsala Region were obtained from SNQ. Cause of death was determined according to ICD-10 codes⁸. Definitive COD was determined from autopsy records for those who underwent autopsy (n = 203). For the rest (n = 75), MDCs and discharge notes were used for definitive

Congenital anomalies	Intraventricular hemorrhage
Neural anomaly	Infection/sepsis
Cardiac anomaly	Infection/sepsis, early
Other anomaly	Infection/sepsis, late
Chromosomal abnormalities	Necrotizing enterocolitis (NEC)
Asphyxia	NEC without sepsis
Intrauterine	NEC with sepsis
Perinatal	Other
Postnatal	Shock/anemia/bleeding
Respiratory causes	Volvulus/malrotation
Bronchopulmonary dysplasia	Isolated spontaneous intestinal perforation
Respiratory distress syndrome	Metabolic/electrolyte/endocrine disorders
Pulmonary hypoplasia	Tumor
Persistent pulmonary hypertension	Twin-to-twin transfusion syndrome
Pneumothorax	CNS-related
Haemothorax	Other
Miscellaneous	Prematurity

Table 4. Categories for causes of death.

COD. Causes of death were categorized by groups based on ICE¹⁰ and further refined in alignment with categories used in recent publications^{11–13}. The final categories are presented in Table 4. The categories were established prior to data collection, to avoid the categorization being influenced by the data.

For autopsied infants, MDCs were examined to compare preliminary and definitive COD. If the MDC was issued after autopsy findings, the discharge note was examined to determine the presumed COD prior to autopsy. The preliminary COD and the definitive COD were compared to see if the definitive COD was altered due to information arising from the autopsy. The outcome after autopsy could be one of three: no change of COD; revised COD; or confirmed suspected but not yet established COD. Suspected COD could for instance be a suspected infection, but without positive cultures or identification of the location of the infection. If COD from the autopsy was “Prematurity” (n = 10), but the clinicians found a more precise COD, the more precise COD was used as the definitive COD, in line with the recommendations from the WHO⁸.

Statistical analyses. Descriptive statistics were calculated in Excel, Version 15.27 (161010). The rest of the statistical analysis was performed in SPSS version 26. A *p* value < 0.05 was considered significant. Comparisons between groups for continuous data were done using the Mann–Whitney U-test. For trend difference analysis in COD from 2002 to 2009 (n = 105) and 2011–2018 (n = 160), both autopsied and not autopsied infants were included. A chi-square test was used to compare the frequency of each diagnosis between the two periods, and complemented with a Fisher’s exact test if less than 5 occurrences were observed. The comparison between preliminary COD and definitive COD according to autopsy was performed on autopsied individuals from 2002 to 2018 (n = 203).

Data availability

All data generated or analyzed during this study are included in this published article (and its Supplementary Information files).

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Author contributions

A.H. performed the collection of data, statistical analysis, wrote and edited the manuscript. L.M. contributed through data analysis, writing and revising of the manuscript. K.E. performed all autopsies included in this study and assisted in data collection. L.D.N. partook in data analysis as well as writing and revising the manuscript. R.S. was the one to set up the study and further partook in data collection, data analysis, writing and revising of the manuscript. The manuscript has been read and approved for submission by all authors.

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Competing interests

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